GATE Chemistry

Sample Paper – 6

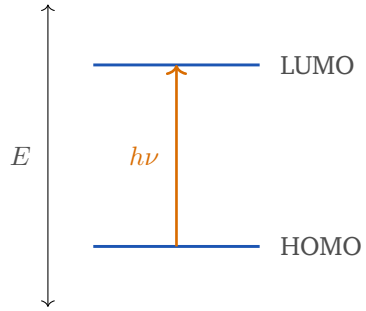
Duration: 128 Minutes **Maximum Marks: 72**

Instructions

- This paper contains **46 questions** covering the core **Chemistry (CY)** subject of the GATE paper conducted by the IITs and IISc (General Aptitude and Engineering Mathematics are provided as separate papers).
- **Q1–Q20 carry 1 mark each** and **Q21–Q46 carry 2 marks each**, for a total of **72 marks**.
- Each question carries **negative marking of one-third of its allotted marks**: a wrong 1-mark question costs **0.33** and a wrong 2-mark question costs **0.67**. Unattempted questions carry no penalty.
- Every question here is a single-correct **MCQ**. The real GATE paper also has Multiple Select (MSQ) and Numerical Answer Type (NAT) questions, and **those carry no negative marking**.
- Attempt this paper in one timed sitting of about **128 minutes**, the share this core subject earns at GATE's overall pace of 180 minutes for 65 questions. Take $R = 8.314\ \mathrm{J\,mol^{-1}K^{-1}}$, $F = 96500\ \mathrm{C\,mol^{-1}}$ and $N_A = 6.022 \times 10^{23}\ \mathrm{mol^{-1}}$ unless stated otherwise.

Physical Chemistry: Quantum Chemistry and Spectroscopy

Q1. An organic dye shows a UV–Vis absorption maximum at $\lambda = 500\ \mathrm{nm}$, corresponding to promotion of one electron from the HOMO to the LUMO as sketched below. Using $E = \dfrac{hc}{\lambda}$ with $h = 6.626 \times 10^{-34}\ \mathrm{J\,s}$ and $c = 3.0 \times 10^{8}\ \mathrm{m\,s^{-1}}$, the energy of a single absorbed photon is nearest to: **[1 mark]**



(A) 3.98×10^{-19} J

(B) 3.98×10^{-17} J

(C) 1.99×10^{-19} J

(D) 6.63×10^{-19} J

Q2. In UV–Vis spectroscopy the common electronic transitions of an organic molecule are $n \to \pi^*$, $\pi \to \pi^*$, $\sigma \to \sigma^*$ and $n \to \sigma^*$. The transition that requires the *least* energy (i.e. absorbs at the longest wavelength) is generally the: **[1 mark]**

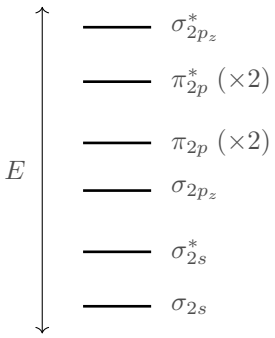
(A) $n \to \pi^*$ transition

(B) $\sigma \to \sigma^*$ transition

(C) $\pi \to \pi^*$ transition

(D) $n \to \sigma^*$ transition

Q3. The molecular-orbital energy ordering for the second-period diatomics is shown below. The superoxide ion O_2^- has 17 valence electrons; filling the ladder places 10 electrons in bonding and 7 in antibonding orbitals. The bond order of O_2^- is: **[1 mark]**



(A) 2.5

(B) 3

(C) 2

(D) 1.5

Q4. For a diatomic molecule to show a pure vibrational (infrared) absorption, its dipole moment must change during the vibration. Among the following, the molecule that is *infrared inactive* for its stretching vibration is: **[1 mark]**

(A) HCl

(B) CO

(C) $\mathrm{N_2}$

(D) HF

Q5. The number of normal (fundamental) modes of vibration of a *non-linear* molecule containing N atoms is $3N - 6$. For the bent water molecule $\mathrm{H_2O}$ (with $N = 3$ atoms), this number is: **[1 mark]**

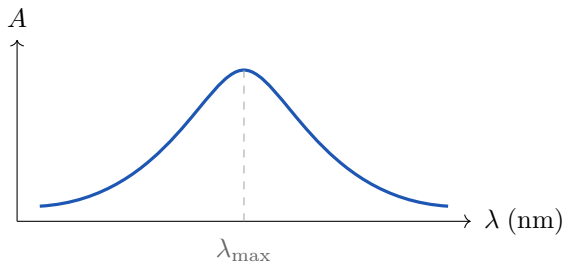
(A) 6

(B) 4

(C) 3

(D) 9

Q6. A coloured solution of concentration $c = 2.0 \times 10^{-4}\ \mathrm{mol\,L^{-1}}$ in a $1\ \mathrm{cm}$ cell shows an absorbance $A = 0.40$ at its $\lambda_{\max}$ (see band below). Using the Beer–Lambert law $A = \varepsilon c l$, the molar absorptivity ε of the species is: **[1 mark]**



(A) $800\ \mathrm{L\,mol^{-1}cm^{-1}}$

(B) $2000\ \mathrm{L\,mol^{-1}cm^{-1}}$

(C) $0.40\ \mathrm{L\,mol^{-1}cm^{-1}}$

(D) $5000\ \mathrm{L\,mol^{-1}cm^{-1}}$

Physical Chemistry: Thermodynamics, Kinetics and Electrochemistry

Q7. An ideal gas is expanded *adiabatically* and reversibly. For this process, the heat exchanged with the surroundings, q, is: **[1 mark]**

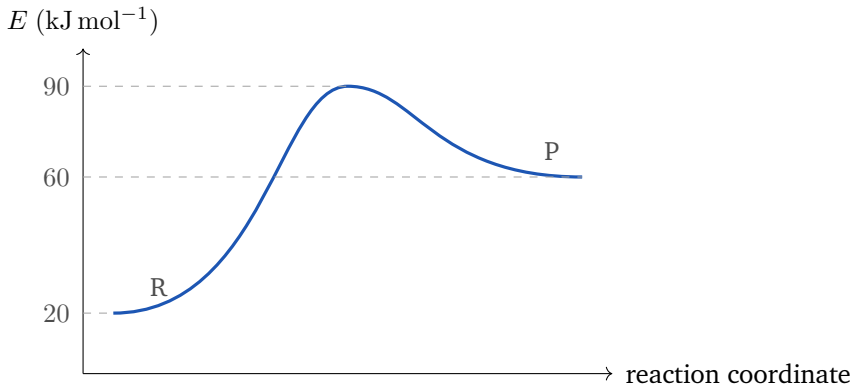
(A) equal to $+w$

(B) equal to ΔU

(C) equal to $-w$

(D) zero

Q8. The reaction-coordinate (potential-energy) diagram of a one-step reaction is shown below. The reactants lie at $20\ \mathrm{kJ\,mol^{-1}}$, the transition state at $90\ \mathrm{kJ\,mol^{-1}}$ and the products at $60\ \mathrm{kJ\,mol^{-1}}$. The enthalpy change of the reaction, $\Delta H = E(\text{products}) - E(\text{reactants})$, is: **[1 mark]**



(A) $+40\ \mathrm{kJ\,mol^{-1}}$

(B) $+70\ \mathrm{kJ\,mol^{-1}}$

(C) $-40\ \mathrm{kJ\,mol^{-1}}$

(D) $+90\ \mathrm{kJ\,mol^{-1}}$

Q9. For a reaction with rate law rate $= k[A]^n$, it is observed that when the concentration of A is doubled (all else fixed), the rate increases by a factor of four. The order of the reaction with respect to A, n, is: **[1 mark]**

(A) 0

(B) 1

(C) 2

(D) 3

Q10. A galvanic cell is built from a silver electrode and a copper electrode. The standard reduction potentials are $E^\circ(\mathrm{Ag^+/Ag}) = +0.80\ \mathrm{V}$ and $E^\circ(\mathrm{Cu^{2+}/Cu}) = +0.34\ \mathrm{V}$. The standard cell potential E°_{cell} is: **[1 mark]**

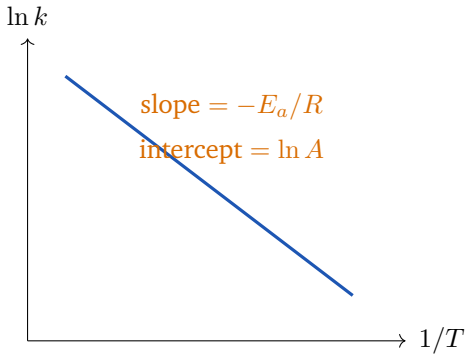
(A) $0.46\ \mathrm{V}$

(B) $1.14\ \mathrm{V}$

(C) $-0.46\ \mathrm{V}$

(D) $0.80\ \mathrm{V}$

Q11. The temperature dependence of a rate constant follows the Arrhenius equation $k = A\,e^{-E_a/RT}$. A plot of $\ln k$ against $1/T$ is a straight line, as shown. The *intercept* of this line (its value extrapolated to $1/T = 0$) is: **[1 mark]**



(A) $-E_a/R$

(B) $+E_a/R$

(C) A

(D) $\ln A$

Q12. An endothermic reaction has $\Delta H = +30\ \text{kJ mol}^{-1}$ and $\Delta S = +100\ \text{J mol}^{-1}\text{K}^{-1}$, both taken as temperature independent. Using $\Delta G = \Delta H - T\Delta S$, the temperature above which the reaction becomes spontaneous ($\Delta G < 0$) is: **[1 mark]**

(A) $300\ \text{K}$

(B) $30\ \text{K}$

(C) $3000\ \text{K}$

(D) $100\ \text{K}$

Q13. A charge of exactly $96500\ \text{C}$ is passed through molten AlCl_3. Aluminium is deposited by the reduction $\text{Al}^{3+} + 3e^- \rightarrow \text{Al}$. The number of moles of aluminium metal deposited is: **[1 mark]**

(A) $\dfrac{1}{3}\ \text{mol}$

(B) $1\ \text{mol}$

(C) $3\ \text{mol}$

(D) $\dfrac{1}{2}\ \text{mol}$

Q14. A reaction follows first-order kinetics with a half-life $t_{1/2}$. Starting from pure reactant, the fraction of reactant still remaining after a time equal to *two* half-lives has elapsed is: **[1 mark]**

(A) 50%

(B) 25%

(C) 12.5%

(D) 75%

Inorganic Chemistry: Main Group and Periodic Properties

Q15. Among the alkali metals Li, Na, K and Cs, the element having the *largest* atomic radius is: **[1 mark]**

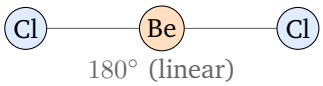
(A) Li

(B) Na

(C) Cs

(D) K

Q16. In gaseous beryllium chloride $\mathrm{BeCl_2}$, the central beryllium atom is surrounded by two bonding pairs and no lone pair, as shown. According to VSEPR theory, the shape of the $\mathrm{BeCl_2}$ molecule is: **[1 mark]**



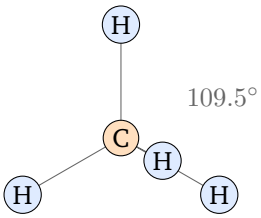
(A) bent

(B) linear

(C) tetrahedral

(D) trigonal planar

Q17. In the methane molecule $\mathrm{CH_4}$, the central carbon is bonded to four hydrogen atoms directed to the corners of a regular tetrahedron with $\mathrm{H-C-H}$ angles of 109.5°, as shown. The hybridization of the central carbon atom is: **[1 mark]**



(A) sp

(B) sp^3

(C) sp^2

(D) sp^3d

Q18. In potassium permanganate $\mathrm{KMnO_4}$, potassium is $+1$ and each oxygen is -2; the compound is neutral. The oxidation state of manganese in $\mathrm{KMnO_4}$ is: **[1 mark]**

(A) $+2$

(B) $+4$

(C) $+6$

(D) $+7$

Q19. On descending group 1 of the periodic table from lithium (Li) to caesium (Cs), the first ionization energy of the alkali metals generally: **[1 mark]**

(A) decreases

(B) increases

(C) stays essentially constant

(D) first decreases and then increases

Q20. Alkaline-earth and alkali metal salts impart characteristic colours to a Bunsen flame. Among the following, the metal whose salts give a *brick-red* flame colouration is: **[1 mark]**

(A) Na

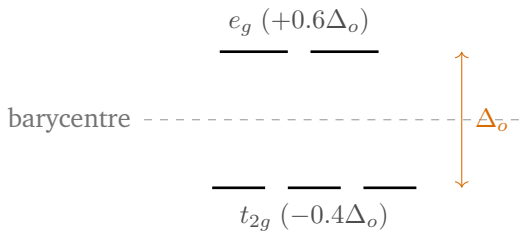
(B) K

(C) Ca

(D) Ba

Inorganic Chemistry: Coordination Compounds and Organometallics

Q21. In an octahedral crystal field the five d orbitals split into a lower t_{2g} set at $-0.4\Delta_o$ and an upper e_g set at $+0.6\Delta_o$ (see below). For a *high-spin* d^6 ion the occupancy is $t_{2g}^4\, e_g^2$. Ignoring the pairing-energy term, the crystal-field stabilization energy (CFSE) is: **[2 marks]**



(A) $-2.4\,\Delta_o$

(B) $-1.2\,\Delta_o$

(C) $-0.4\,\Delta_o$

(D) 0

Q22. The hexacarbonylvanadium complex $[\mathrm{V(CO)_6}]$ is counted by the neutral (covalent) method: vanadium(0) of group 5 contributes 5 valence electrons and each CO donates 2 electrons. The total valence electron count of $[\mathrm{V(CO)_6}]$ is: **[2 marks]**

(A) 18

(B) 16

(C) 20

(D) 17

Q23. The octahedral complex $[\mathrm{Ti(H_2O)_6}]^{3+}$ contains a d^1 titanium(III) centre with one unpaired electron. Using the spin-only formula $\mu = \sqrt{n(n+2)}\ \mathrm{BM}$, the magnetic moment of the complex is nearest to: **[2 marks]**

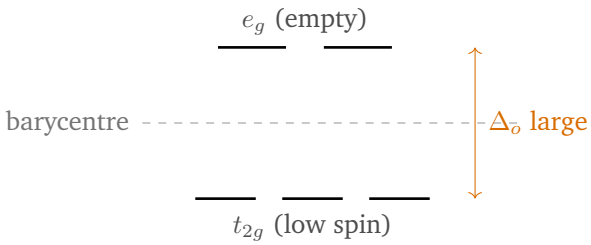
(A) $1.73\ \mathrm{BM}$

(B) $2.83\ \mathrm{BM}$

(C) $3.87\ \mathrm{BM}$

(D) $0\ \mathrm{BM}$

Q24. The strong-field ligand $\mathrm{CN^-}$ makes $[\mathrm{Fe(CN)_6}]^{3-}$ a *low-spin* d^5 complex, so all five d electrons occupy the lower t_{2g} set as shown. The number of unpaired electrons in $[\mathrm{Fe(CN)_6}]^{3-}$ is: **[2 marks]**



(A) 5

(B) 3

(C) 1

(D) 0

Q25. The chelating ligand ethylenediaminetetraacetate ($EDTA^{4-}$) is a hexadentate ligand, binding a metal ion through all of its donor atoms at once. The number of coordination sites that one $EDTA^{4-}$ ion occupies on a central metal ion is: **[2 marks]**

(A) 2

(B) 4

(C) 6

(D) 1

Q26. Among the ligands CO, H_2O, Cl^- and OH^-, the one that lies highest in the spectrochemical series and produces the *largest* crystal-field splitting (a strong σ-donor and π-acceptor) is: **[2 marks]**

(A) CO

(B) H_2O

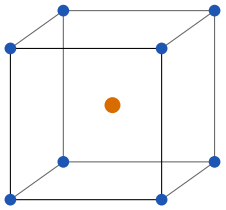
(C) Cl^-

(D) OH^-

Inorganic Chemistry: Solid State and Bioinorganic

Q27. Many metals such as α-iron crystallize in the body-centred cubic (BCC) structure shown below, with atoms at the eight corners and one at the

body centre. In this arrangement, the coordination number of each atom (the number of nearest neighbours) is: [2 marks]



(A) 6

(B) 8

(C) 12

(D) 4

Q28. Brass is one of the most widely used substitutional alloys, valued for its strength and corrosion resistance. Brass is essentially an alloy of copper with which other metal? [2 marks]

(A) tin

(B) zinc

(C) lead

(D) nickel

Q29. Chlorophyll, the green pigment responsible for photosynthesis, is a magnesium–porphyrin complex in which a single metal ion sits at the centre of the porphyrin ring. The metal ion present at the centre of chlorophyll is: [2 marks]

(A) Fe^{2+}

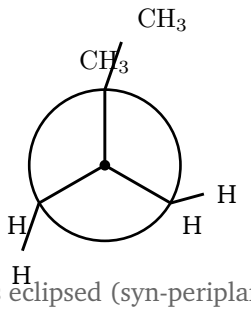
(B) Zn^{2+}

(C) Ca^{2+}

(D) Mg^{2+}

Organic Chemistry: Stereochemistry and Reaction Mechanisms

Q30. A Newman projection of n-butane, viewed along the $C2-C3$ bond, is shown below with the two methyl groups eclipsing each other at the top. Of all the conformations of n-butane about this bond, the one of *highest* energy is the one in which the two methyl groups are: **[2 marks]**



methyls eclipsed (syn-periplanar)

(A) anti (180° dihedral)

(B) gauche (60° dihedral)

(C) eclipsed with a methyl opposite a hydrogen

(D) syn-periplanar, fully eclipsed with the two methyls together (0°)

Q31. A molecule has two stereogenic centres but also possesses an internal plane of symmetry (as in tartaric acid), which makes one of the possible stereoisomers a meso form. The total number of distinct stereoisomers this molecule can have is: **[2 marks]**

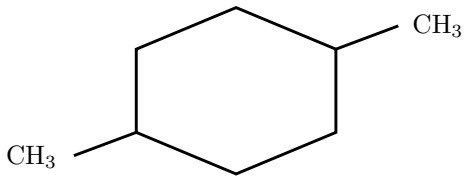
(A) 4

(B) 3

(C) 2

(D) 1

Q32. The most stable chair conformation of *trans*-$1,2$-dimethylcyclohexane is shown below. To minimize $1,3$-diaxial strain, the two methyl substituents preferentially adopt which arrangement? **[2 marks]**



trans-1,2-dimethylcyclohexane

(A) both axial (diaxial)

(B) both equatorial (diequatorial)

(C) one axial and one equatorial

(D) it makes no difference to the energy

Q33. The tertiary alkyl halide *tert*-butyl bromide $(CH_3)_3C{-}Br$ is solvolysed in aqueous ethanol, a polar protic solvent, with a weak nucleophile. Substitution proceeds predominantly by which mechanism? **[2 marks]**

(A) S_N1

(B) S_N2

(C) $E2$

(D) $E1cb$

Q34. In the electrophilic addition of HBr to propene ($CH_3CH{=}CH_2$), the proton adds first and the reaction proceeds through the more stable carbocation intermediate. The carbocation that forms preferentially is the: **[2 marks]**

(A) secondary (2°) carbocation

(B) primary (1°) carbocation

(C) methyl carbocation

(D) primary carbanion

Q35. Electrophilic addition of bromine (Br_2) to cyclohexene passes through a cyclic bromonium-ion intermediate, so the second bromide attacks from the opposite face (anti addition). The major product of this reaction is: **[2 marks]**

(A) *cis*-1,2-dibromocyclohexane

(B) *trans*-1,2-dibromocyclohexane

(C) 1,1-dibromocyclohexane

(D) 1,3-dibromocyclohexane

Q36. When HBr is added to propene in the *presence of organic peroxides* (the Kharasch peroxide effect), the addition follows a free-radical mechanism and goes against Markovnikov's rule. The major product is: **[2 marks]**

(A) 1-bromopropane

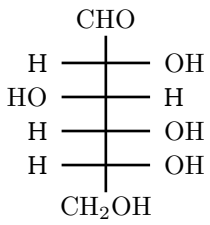
(B) 2-bromopropane

(C) propan-2-ol

(D) 2-bromobutane

Organic Chemistry: Named Reactions and Synthesis

Q37. The open-chain form of D-glucose is shown below. Because it contains a free reactive group in this form, glucose reduces Tollens' reagent to give a silver mirror and is therefore called a reducing sugar. The functional group responsible for this behaviour is a free: **[2 marks]**



open-chain D-glucose

(A) ketone group

(B) carboxylic acid group

(C) aldehyde group

(D) ester group

Q38. A gentle oxidant is needed to convert a primary alcohol RCH_2OH selectively to the aldehyde RCHO *without* over-oxidation to the carboxylic acid. The reagent that best achieves this selective, controlled oxidation is: **[2 marks]**

(A) hot acidic $KMnO_4$

(B) acidic $K_2Cr_2O_7$

(C) Jones reagent (CrO_3/H_2SO_4)

(D) pyridinium chlorochromate (PCC)

Q39. The controlled reduction of an acyl chloride $RCOCl$ to an aldehyde $RCHO$, using hydrogen gas over a palladium catalyst poisoned with barium sulfate, is a classic named reaction. This selective reduction is the: **[2 marks]**

(A) Clemmensen reduction

(B) Rosenmund reduction

(C) Wolff–Kishner reduction

(D) Birch reduction

Q40. In the Friedel–Crafts alkylation of benzene with methyl chloride CH_3Cl in the presence of anhydrous $AlCl_3$, the Lewis acid abstracts chloride to generate the true attacking electrophile, which is the: **[2 marks]**

(A) chloronium ion, Cl^+

(B) methyl carbocation, CH_3^+

(C) tetrachloroaluminate ion, $AlCl_4^-$

(D) methyl radical, $CH_3^\bullet$

Q41. When D-glucose is treated with an excess of phenylhydrazine, both the $C1$ aldehyde and the $C2$ hydroxyl react to give a characteristic crystalline bis-phenylhydrazone derivative used historically to identify sugars. This product is a(n): **[2 marks]**

(A) glycoside

(B) ester

(C) gluconic acid

(D) osazone (glucosazone)

Q42. A ketone carbonyl $\mathrm{C{=}O}$ can be reduced all the way to a methylene group $\mathrm{CH_2}$ under *basic* conditions by heating with hydrazine ($\mathrm{NH_2NH_2}$) and a strong base such as KOH. This carbonyl-to-methylene reduction is the: [2 marks]

(A) Clemmensen reduction

(B) Wolff–Kishner reduction

(C) Rosenmund reduction

(D) Birch reduction

Q43. In the disaccharide sucrose (table sugar), one glucose unit and one fructose unit are joined together through their anomeric carbons. Chemically, the linkage that joins the two monosaccharide units is a(n): [2 marks]

(A) peptide bond

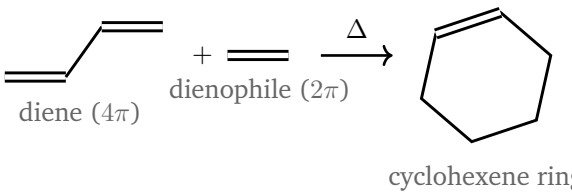
(B) ester bond

(C) glycosidic bond

(D) ether linkage within a single ring

Organic Chemistry: Pericyclic, Photochemistry and Biomolecules

Q44. The reaction of a conjugated diene (4π electrons) with a dienophile (2π electrons) to form a six-membered ring, as sketched below, is thermally allowed and forms two new σ bonds in one concerted step. In the Woodward–Hoffmann classification, the Diels–Alder reaction is a: [2 marks]



(A) $[2+2]$ cycloaddition

(B) $[1,3]$ sigmatropic shift

(C) electrocyclic ring opening

(D) $[4+2]$ cycloaddition

Q45. A conjugated triene has six π electrons ($4n+2$, $n=1$). Under *photochemical* excitation, the Woodward–Hoffmann rules invert relative to the thermal case. The stereochemical mode of the photochemical 6π electrocyclic ring closure is: [2 marks]

(A) disrotatory

(B) forbidden (does not occur)

(C) conrotatory

(D) suprafacial–suprafacial

Q46. The two cyclic anomers of D-glucose, α-D-glucopyranose and β-D-glucopyranose, are diastereomers that interconvert in solution (mutarotation). The two anomers differ in configuration at exactly one carbon, the anomeric carbon, which is: [2 marks]

(A) C6

(B) C4

(C) C2

(D) C1

Detailed Solutions

Q1.

Solution

Concept – photon energy from wavelength: The energy carried by one photon is $E = \dfrac{hc}{\lambda}$, using SI units throughout.

Step 1 – convert the wavelength to metres: $\lambda = 500\ \text{nm} = 500 \times 10^{-9}\ \text{m} = 5.0 \times 10^{-7}\ \text{m}$

Step 2 – form the product hc in the numerator: $hc = (6.626 \times 10^{-34})(3.0 \times 10^{8})$

$hc = 1.988 \times 10^{-25}\ \text{J m}$

Step 3 – divide by λ: $E = \dfrac{1.988 \times 10^{-25}}{5.0 \times 10^{-7}}$

Step 4 – evaluate: $E = 3.98 \times 10^{-19}\ \text{J}$

Why the others are wrong: 3.98×10^{-17} J misplaces the power of ten; 1.99×10^{-19} J uses 2λ; 6.63×10^{-19} J forgets to include c correctly.

Final Answer: $E = 3.98 \times 10^{-19}\ \text{J} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept – relative energies of electronic transitions: The energy needed to excite an electron follows the order $n \to \pi^* < n \to \sigma^* < \pi \to \pi^* < \sigma \to \sigma^*$.

Step 1 – locate the highest occupied level involved: Non-bonding (n) electrons lie at higher energy than π or σ bonding electrons, so they are the easiest to promote.

Step 2 – locate the lowest empty level involved: The π^* antibonding orbital lies below the σ^* orbital.

Step 3 – combine to find the smallest gap: Starting from the high-lying n level and ending at the low-lying π^* level gives the smallest energy gap, i.e. the longest-wavelength absorption.

Step 4 – conclude: The $n \to \pi^*$ transition therefore requires the least energy.

Final Answer: lowest-energy transition $= n \to \pi^* \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept – bond order from MO populations: Bond order $= \dfrac{N_b - N_a}{2}$, where N_b and N_a are the bonding and antibonding electron counts.

Step 1 – count the electrons of O_2^-: Neutral O_2 has 16 electrons; the extra electron of O_2^- gives 17 electrons.

Step 2 – assign bonding and antibonding populations: Filling the ladder gives $N_b = 10$ (bonding) and $N_a = 7$ (antibonding); the added electron enters a π^*_{2p} orbital.

Step 3 – substitute into the formula: Bond order $= \dfrac{10 - 7}{2}$

Step 4 – evaluate: Bond order $= \dfrac{3}{2} = 1.5$

Step 5 – cross-check: This is lower than the value of 2 for O_2, consistent with the weaker, longer bond of the superoxide ion.

Final Answer: bond order of $O_2^- = 1.5 \Rightarrow \boxed{D}$

Answer: (D) Go Back to Q3

Q4.

Solution

Concept – infrared (vibrational) selection rule: A vibration is IR active only if it produces a change in the molecular dipole moment.

Step 1 – examine the heteronuclear molecules: HCl, CO and HF are all polar; stretching them changes the dipole moment, so they are IR active.

Step 2 – examine N_2: N_2 is homonuclear and has zero dipole moment; stretching the bond keeps the dipole at zero.

Step 3 – apply the selection rule: With no change in dipole moment, the N_2 stretch cannot absorb infrared radiation.

Final Answer: IR-inactive molecule $= N_2 \Rightarrow \boxed{C}$

Answer: (C) Go Back to Q4

Q5.

Solution

Concept – vibrational degrees of freedom: A non-linear molecule has $3N - 6$ vibrational modes; a linear one has $3N - 5$.

Step 1 – identify the geometry of water: H_2O is bent (non-linear), so the correct formula is $3N - 6$.

Step 2 – insert the number of atoms: $N = 3$, so number of modes $= 3(3) - 6$

Step 3 – evaluate: $= 9 - 6 = 3$

Step 4 – name the three modes: symmetric stretch, asymmetric stretch and bend $= 3$ in all, which matches.

Final Answer: number of vibrational modes $= 3 \Rightarrow$ C

Answer: (C) Go Back to Q5

Q6.

Solution

Concept – Beer–Lambert law: $A = \varepsilon c l$, so $\varepsilon = \dfrac{A}{c\,l}$.

Step 1 – list the given quantities: $A = 0.40$, $c = 2.0 \times 10^{-4}\ \text{mol L}^{-1}$, $l = 1\ \text{cm}$.

Step 2 – rearrange for ε: $\varepsilon = \dfrac{A}{c\,l} = \dfrac{0.40}{(2.0 \times 10^{-4})(1)}$

Step 3 – evaluate the denominator: $c\,l = 2.0 \times 10^{-4}\ \text{mol L}^{-1}\text{cm}$

Step 4 – divide: $\varepsilon = \dfrac{0.40}{2.0 \times 10^{-4}} = 2000\ \text{L mol}^{-1}\text{cm}^{-1}$

Final Answer: $\varepsilon = 2000\ \text{L mol}^{-1}\text{cm}^{-1} \Rightarrow$ B

Answer: (B) Go Back to Q6

Q7.

Solution

Concept – definition of an adiabatic process: An adiabatic process is one in which no heat is exchanged with the surroundings.

Step 1 – state the defining condition: For an adiabatic change, by definition $q = 0$.

Step 2 – apply the first law: $\Delta U = q + w = 0 + w = w$, so the internal-energy change comes entirely from work.

Step 3 – answer what was asked: The question asks only for the heat exchanged

q, which is exactly zero.

Why the others are wrong: $q = w$ or $q = \Delta U$ would require a non-adiabatic path; the whole point of "adiabatic" is $q = 0$.

Final Answer: $q = 0 \Rightarrow$ D

Answer: (D) Go Back to Q7

Q8.

Solution

Concept – enthalpy change from a reaction-coordinate diagram: $\Delta H = E(\text{products}) - E(\text{reactants})$, read off the two plateaus.

Step 1 – read the levels: Reactants $= 20\ \text{kJ mol}^{-1}$, products $= 60\ \text{kJ mol}^{-1}$.

Step 2 – subtract: $\Delta H = 60 - 20$

Step 3 – evaluate: $\Delta H = +40\ \text{kJ mol}^{-1}$

Step 4 – interpret and cross-check: The positive sign shows the reaction is endothermic; also $E_a(\text{forward}) = 90 - 20 = 70$ and $E_a(\text{reverse}) = 90 - 60 = 30$, and $70 - 30 = 40 = \Delta H$, which is consistent.

Final Answer: $\Delta H = +40\ \text{kJ mol}^{-1} \Rightarrow$ A

Answer: (A) Go Back to Q8

Q9.

Solution

Concept – order of reaction from concentration dependence: For rate $= k[A]^n$, multiplying $[A]$ by a factor multiplies the rate by that factor raised to the power n.

Step 1 – write the two rates: Initial: $r_1 = k[A]^n$. After doubling: $r_2 = k(2[A])^n$.

Step 2 – take the ratio: $\dfrac{r_2}{r_1} = \dfrac{k(2[A])^n}{k[A]^n} = 2^n$

Step 3 – insert the observed factor: The rate quadruples, so $2^n = 4$.

Step 4 – solve for n: $2^n = 2^2$, hence $n = 2$.

Final Answer: order in A is $n = 2 \Rightarrow$ C

Answer: (C) Go Back to Q9

Q10.

Solution

Concept – standard cell potential: $E^\circ_{\text{cell}} = E^\circ_{\text{cathode}} - E^\circ_{\text{anode}}$, using reduction potentials.

Step 1 – identify cathode and anode: The more positive potential is reduced, so Ag^+/Ag $(+0.80\ \text{V})$ is the cathode and Cu^{2+}/Cu $(+0.34\ \text{V})$ is the anode.

Step 2 – substitute the reduction potentials: $E^\circ_{\text{cell}} = (+0.80) - (+0.34)$

Step 3 – evaluate: $E^\circ_{\text{cell}} = 0.46\ \text{V}$

Step 4 – sanity check: $E^\circ_{\text{cell}} > 0$, so the cell reaction is spontaneous, as expected.

Why the others are wrong: $1.14\ \text{V}$ adds the two potentials; $-0.46\ \text{V}$ swaps cathode and anode; $0.80\ \text{V}$ ignores the copper electrode.

Final Answer: $E^\circ_{\text{cell}} = 0.46\ \text{V} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q10

Q11.

Solution

Concept – linearized Arrhenius equation: Taking natural logs of $k = A\,e^{-E_a/RT}$ gives $\ln k = \ln A - \dfrac{E_a}{R} \cdot \dfrac{1}{T}$.

Step 1 – compare with $y = c + mx$: Here $y = \ln k$ and $x = \dfrac{1}{T}$.

Step 2 – identify the intercept c: The constant term is $c = \ln A$, the value of $\ln k$ as $\dfrac{1}{T} \to 0$.

Step 3 – identify the slope for completeness: The coefficient of $\dfrac{1}{T}$ is $m = -\dfrac{E_a}{R}$ (the slope, not the intercept).

Step 4 – answer what was asked: The intercept of the line is $\ln A$.

Final Answer: intercept $= \ln A \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q11

Q12.

Solution

Concept – temperature for spontaneity: A reaction turns spontaneous when $\Delta G = \Delta H - T\Delta S < 0$; the crossover is at $\Delta G = 0$, giving $T = \dfrac{\Delta H}{\Delta S}$.

Step 1 – put both quantities in joules: $\Delta H = +30\ \text{kJ mol}^{-1} = +30000\ \text{J mol}^{-1}$, $\Delta S = +100\ \text{J mol}^{-1}\text{K}^{-1}$.

Step 2 – set $\Delta G = 0$: $0 = \Delta H - T\Delta S$

Step 3 – solve for the crossover temperature: $T = \dfrac{\Delta H}{\Delta S} = \dfrac{30000}{100}$

Step 4 – evaluate: $T = 300\ \text{K}$

Step 5 – interpret: Since both ΔH and ΔS are positive, the reaction is spontaneous only *above* 300 K.

Final Answer: $T = 300\ \text{K} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q12

Q13.

Solution

Concept – Faraday's law of electrolysis: Depositing one mole of a species needing n electrons requires n moles of electrons, i.e. $Q = (\text{moles deposited}) \times nF$.

Step 1 – read the electrode reaction: $\text{Al}^{3+} + 3e^- \rightarrow \text{Al}$, so $n = 3$ electrons per aluminium atom.

Step 2 – write the moles of electrons passed: moles of $e^- = \dfrac{Q}{F} = \dfrac{96500}{96500} = 1\ \text{mol}$

Step 3 – convert electrons to moles of Al: moles of Al $= \dfrac{\text{moles of } e^-}{3} = \dfrac{1}{3}$

Step 4 – state the result: $\dfrac{1}{3}$ mol of aluminium is deposited.

Final Answer: moles of Al $= \dfrac{1}{3} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q13

Q14.

Solution

Concept – fraction remaining after n half-lives: For any first-order decay, each half-life leaves half of what was present, so after n half-lives the fraction remaining is $\left(\frac{1}{2}\right)^n$.

Step 1 – set the number of half-lives: Two half-lives have elapsed, so $n = 2$.

Step 2 – apply the halving rule: fraction remaining $= \left(\frac{1}{2}\right)^2$

Step 3 – evaluate: $= \frac{1}{4}$

Step 4 – express as a percentage: $\frac{1}{4} = 25\%$

Final Answer: fraction remaining $= 25\% \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q14

Q15.

Solution

Concept – atomic-radius trend down a group: Going down a group, each element adds a new principal shell, so the atomic radius steadily increases.

Step 1 – order the alkali metals by period: Li (period 2) $<$ Na (3) $<$ K (4) $<$ Cs (6).

Step 2 – apply the trend: More occupied shells means a larger radius, so the lowest member listed has the largest radius.

Step 3 – pick the largest: Of Li, Na, K, Cs, caesium sits lowest and therefore has the largest atomic radius.

Final Answer: largest atomic radius $=$ Cs $\Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q15

Q16.

Solution

Concept – VSEPR geometry from the steric number: Shape follows from the number of electron domains around the central atom.

Step 1 – count the domains on beryllium in $BeCl_2$: Two Be$-$Cl bonding pairs and no lone pair give a steric number of 2.

Step 2 – map the steric number to a shape: Two electron domains arrange themselves as far apart as possible, i.e. at 180°.

Step 3 – name the geometry: A 180° arrangement of two bonds is linear, matching the figure.

Final Answer: shape of $BeCl_2$ is linear $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q16

Q17.

Solution

Concept – hybridization from the number of electron domains: Two domains give sp, three give sp^2, four give sp^3.

Step 1 – count the domains on carbon in CH_4: Four $C-H$ bonds and no lone pair give four electron domains.

Step 2 – assign the hybridization: Four domains correspond to sp^3 hybridization.

Step 3 – confirm with the geometry: sp^3 gives a tetrahedral shape with 109.5° bond angles, exactly as drawn.

Final Answer: carbon is sp^3 hybridized $\Rightarrow$ B

Answer: (B) Go Back to Q17

Q18.

Solution

Concept – oxidation state from charge balance: The sum of the oxidation states in a neutral compound is zero.

Step 1 – let the oxidation state of manganese be x: Potassium is $+1$ and each of the four oxygens is -2.

Step 2 – write the balance for $KMnO_4$: $(+1) + x + 4(-2) = 0$

Step 3 – simplify: $1 + x - 8 = 0$

Step 4 – solve for x: $x - 7 = 0 \Rightarrow x = +7$

Step 5 – interpret: Mn at its maximum $+7$ state is why $KMnO_4$ is such a strong oxidizing agent.

Final Answer: oxidation state of $Mn = +7 \Rightarrow$ D

Answer: (D) Go Back to Q18

Q19.

Solution

Concept – first-ionization-energy trend down a group: Ionization energy is set by how tightly the outermost electron is held.

Step 1 – track the atomic size: Descending group 1 from Li to Cs, the atoms get larger and the valence electron sits farther from the nucleus.

Step 2 – track the shielding: More inner shells shield the outer electron more effectively, weakening its attraction to the nucleus.

Step 3 – combine the effects: A more distant, better-shielded valence electron is easier to remove.

Step 4 – conclude: The first ionization energy therefore decreases down the group.

Final Answer: first ionization energy decreases $\Rightarrow$ $\boxed{\text{A}}$

Answer: (A) Go Back to Q19

Q20.

Solution

Concept – characteristic flame colours: Each alkali/alkaline-earth metal emits light of a characteristic colour when its electrons relax after thermal excitation.

Step 1 – recall the standard flame colours: Na is golden yellow, K is lilac (pale violet), Ca is brick-red, and Ba is apple-green.

Step 2 – match to the question: The brick-red flame is produced by calcium.

Step 3 – reject the distractors: Sodium gives yellow, potassium violet, and barium green, none of which is brick-red.

Final Answer: brick-red flame $=$ Ca $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q20

Q21.

Solution

Concept – CFSE in an octahedral field: CFSE $= \big[-0.4\,n(t_{2g}) + 0.6\,n(e_g)\big]\Delta_o$, using the electron occupancies.

Step 1 – write the high-spin d^6 occupancy: $t_{2g}^4\, e_g^2$, so $n(t_{2g}) = 4$ and $n(e_g) = 2$.

Step 2 – substitute into the CFSE expression: CFSE $= \big[-0.4(4) + 0.6(2)\big]\Delta_o$

Step 3 – evaluate each term: $-0.4(4) = -1.6$ and $0.6(2) = +1.2$

Step 4 – add inside the bracket: CFSE $= (-1.6 + 1.2)\Delta_o = -0.4\,\Delta_o$

Step 5 – note the assumption: The pairing-energy term is ignored as the question directs, so the orbital CFSE is $-0.4\,\Delta_o$.

Final Answer: CFSE $= -0.4\,\Delta_o \Rightarrow$ C

Answer: (C) Go Back to Q21

Q22.

Solution

Concept – valence electron count (neutral method): Total count = metal valence electrons + electrons donated by the ligands.

Step 1 – count the metal contribution: Vanadium is in group 5; as $V(0)$ it contributes 5 valence electrons.

Step 2 – count the ligand contribution: Each CO donates 2 electrons; six CO give $6 \times 2 = 12$.

Step 3 – add the two contributions: Total $= 5 + 12 = 17$

Step 4 – interpret the result: $[V(CO)_6]$ is one electron short of 18, which is why it is an unusually reactive, paramagnetic 17-electron complex (readily reduced to the 18-electron $[V(CO)_6]^-$).

Final Answer: valence electron count $= 17 \Rightarrow$ D

Answer: (D) Go Back to Q22

Q23.

Solution

Concept – spin-only magnetic moment: $\mu = \sqrt{n(n+2)}$ BM, with n the number of unpaired electrons.

Step 1 – find n for Ti^{3+}: Ti^{3+} is d^1, so it has one unpaired electron, $n = 1$.

Step 2 – substitute into the formula: $\mu = \sqrt{1(1+2)}$

Step 3 – evaluate inside the root: $\mu = \sqrt{1 \times 3} = \sqrt{3}$

Step 4 – take the square root: $\mu = 1.732 \approx 1.73$ BM

Final Answer: $\mu \approx 1.73$ BM $\Rightarrow$ A

Answer: (A) Go Back to Q23

Q24.

Solution

Concept – unpaired electrons in a low-spin d^5 complex: A strong-field ligand makes Δ_o large, so electrons pair up in the lower t_{2g} set before entering e_g.

Step 1 – identify the metal d count: Fe^{3+} is d^5.

Step 2 – apply the strong-field (CN^-) filling: All five electrons crowd into the three t_{2g} orbitals: $t_{2g}^5\, e_g^0$.

Step 3 – count the unpaired electrons: Filling t_{2g} as $\uparrow\downarrow,\ \uparrow\downarrow,\ \uparrow$ leaves exactly one unpaired electron.

Step 4 – state the result: The number of unpaired electrons is 1 (low-spin).

Final Answer: unpaired electrons $= 1 \Rightarrow$ C

Answer: (C) Go Back to Q24

Q25.

Solution

Concept – denticity and coordination sites: The number of sites a ligand occupies equals the number of donor atoms it uses to bind.

Step 1 – recall the denticity of EDTA: $EDTA^{4-}$ binds through two nitrogen atoms and four carboxylate oxygen atoms.

Step 2 – add the donor atoms: $2\ (N) + 4\ (O) = 6$ donor atoms.

Step 3 – relate to coordination sites: Each donor atom takes one coordination site, so EDTA occupies 6 sites and is called hexadentate.

Final Answer: coordination sites occupied $= 6 \Rightarrow$ C

Answer: (C) Go Back to Q25

Q26.

Solution

Concept – spectrochemical series: Ligands are ranked by the splitting they produce; a useful order is $Cl^- < OH^- < H_2O < NH_3 < en < CN^- \approx CO$.

Step 1 – place the four candidates in the series: Cl^- and OH^- are weak-field, H_2O is intermediate, and CO is at the very top.

Step 2 – explain why CO is strongest: CO is both a good σ-donor and a strong π-acceptor, which greatly enlarges Δ_o.

Step 3 – pick the strongest field: CO produces the largest crystal-field splitting of the four.

Final Answer: strongest-field ligand $= \mathrm{CO} \Rightarrow \boxed{\mathrm{A}}$

Answer: (A) Go Back to Q26

Q27.

Solution

Concept – coordination number in a BCC lattice: The coordination number is the count of nearest-neighbour atoms touching a given atom.

Step 1 – pick a reference atom: Take the body-centre atom of the cube.

Step 2 – find its nearest neighbours: It touches the eight corner atoms of the cube, one at each corner.

Step 3 – count them: 8 corner atoms surround the body-centre atom at equal distance.

Step 4 – state the result: Every atom in a BCC lattice has a coordination number of 8.

Final Answer: coordination number $= 8 \Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q27

Q28.

Solution

Concept – composition of common alloys: Brass is a substitutional alloy of two metals whose atoms replace one another in the crystal lattice.

Step 1 – recall the two components of brass: Brass is made of copper and zinc.

Step 2 – reject the distractors: Copper with tin gives bronze; copper (or iron) with lead is a different bearing alloy; copper with nickel gives cupronickel.

Step 3 – conclude: The metal alloyed with copper to make brass is zinc.

Final Answer: brass $=$ copper $+$ zinc $\Rightarrow \boxed{\mathrm{B}}$

Answer: (B) Go Back to Q28

Q29.

Solution

Concept – metal centre of chlorophyll: Chlorophyll is a porphyrin (specifically chlorin) ring holding a single metal ion at its centre.

Step 1 – identify the prosthetic metal: In chlorophyll the central ion is magnesium.

Step 2 – assign its oxidation state: Magnesium is present as Mg^{2+}, coordinated by four ring nitrogen atoms.

Step 3 – reject the distractors: Fe^{2+} is in haemoglobin, Zn^{2+} in carbonic anhydrase, and Ca^{2+} is not a porphyrin centre.

Final Answer: metal in chlorophyll $= \mathrm{Mg}^{2+} \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q29

Q30.

Solution

Concept – conformational energies of n-butane about $\mathrm{C2}-\mathrm{C3}$: Energy rises in the order anti $<$ gauche $<$ (methyl/H) eclipsed $<$ fully eclipsed (syn-periplanar).

Step 1 – identify the sources of strain: Eclipsed conformers suffer torsional (eclipsing) strain; the strain is worst when the two bulky methyls eclipse each other.

Step 2 – compare the eclipsed forms: Methyl-eclipsing-hydrogen is high, but methyl-eclipsing-methyl (syn-periplanar, 0°) adds severe steric repulsion on top of the torsional strain.

Step 3 – pick the maximum: The syn-periplanar, fully eclipsed conformation with the two methyls together is the highest-energy point on the rotation profile, as drawn.

Why the others are wrong: anti is the global minimum; gauche is a shallow local minimum; the methyl/H-eclipsed form is a lower maximum than the syn-periplanar one.

Final Answer: highest-energy $=$ syn-periplanar fully eclipsed $(0^\circ) \Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q30

Q31.

Solution

Concept – stereoisomer count with a meso form: Two stereocentres normally give $2^2 = 4$ stereoisomers, but internal symmetry can make two of them identical (a single meso compound).

Step 1 – start from the naive maximum: For $n = 2$ centres, the upper bound is $2^2 = 4$.

Step 2 – apply the internal plane of symmetry: The (R, S) and (S, R) forms are superimposable mirror images, so they collapse into one achiral meso compound.

Step 3 – recount the distinct isomers: This leaves the (R, R) and (S, S) enantiomeric pair plus the single meso form.

Step 4 – total them: 2 (enantiomers) $+1$ (meso) $= 3$ distinct stereoisomers.

Final Answer: number of stereoisomers $= 3 \Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q31

Q32.

Solution

Concept – axial versus equatorial preference: Bulky substituents prefer equatorial positions to avoid $1, 3$-diaxial steric repulsions.

Step 1 – consider the diaxial chair: If both methyls were axial, each would suffer $1, 3$-diaxial clashes, a high-energy arrangement.

Step 2 – consider the diequatorial chair: For *trans*-$1, 2$-dimethylcyclohexane the geometry allows both methyls to be equatorial at the same time, pointing outward.

Step 3 – compare the two chairs: The diequatorial (e,e) chair is free of $1, 3$-diaxial strain and is much lower in energy.

Step 4 – conclude: The more stable chair has both methyl groups equatorial.

Final Answer: both methyls equatorial (diequatorial) $\Rightarrow \boxed{\text{B}}$

Answer: (B) Go Back to Q32

Q33.

Solution

Concept – mechanism selection for a tertiary substrate: A tertiary carbon forms a stable carbocation, and a polar protic solvent with a weak nucleophile favours a stepwise ionization (S_N1).

Step 1 – assess the carbocation stability: The 3° carbon of *tert*-butyl bromide gives a stable tertiary carbocation on ionization.

Step 2 – assess the conditions: Aqueous ethanol is polar protic and solvates/stabilizes the ion pair, while the weak nucleophile cannot drive a backside attack.

Step 3 – rule out S_N2: The crowded tertiary centre blocks backside attack, so S_N2 is not feasible.

Step 4 – conclude: Substitution proceeds by the two-step S_N1 mechanism (rate-determining ionization, then nucleophile capture).

Final Answer: mechanism is $S_N1 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q33

Q34.

Solution

Concept – Markovnikov addition via the more stable carbocation: In electrophilic addition of HBr to an alkene, H^+ adds so as to generate the more stable carbocation.

Step 1 – identify the two possible cations: Adding H^+ to the terminal CH_2 gives a secondary cation $CH_3-\overset{+}{C}H-CH_3$; adding to the internal carbon would give a primary cation.

Step 2 – compare their stabilities: The secondary cation is stabilized by hyperconjugation and the $+I$ effect of two alkyl groups, far more than the primary cation.

Step 3 – pick the preferred intermediate: The reaction proceeds through the more stable secondary carbocation.

Final Answer: preferred intermediate = secondary carbocation $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q34

Q35.

Solution

Concept – anti (trans) addition through a bromonium ion: Bromine adds to an alkene via a cyclic bromonium ion, and the bromide opens it from the opposite face, giving anti addition.

Step 1 – form the bromonium ion: Br_2 adds across the double bond of cyclohexene to give a three-membered bromonium ring on one face.

Step 2 – open the ring: Br^- attacks a ring carbon from the face opposite the bromonium, placing the two bromines on opposite faces.

Step 3 – identify the stereochemistry: Two bromines on opposite faces of adjacent carbons is the *trans* (anti) diaxial product.

Step 4 – name the product: The major product is *trans*-$1,2$-dibromocyclohexane.

Final Answer: major product $=$ *trans*-$1,2$-dibromocyclohexane $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q35

Q36.

Solution

Concept – Kharasch (peroxide) anti-Markovnikov effect: With peroxides present, HBr adds to an alkene by a free-radical chain mechanism, reversing the regiochemistry to anti-Markovnikov.

Step 1 – generate the bromine radical: Peroxides initiate the chain, producing $Br^{\bullet}$.

Step 2 – add the radical for the more stable carbon radical: $Br^{\bullet}$ adds to the terminal carbon of propene to give the more stable secondary carbon radical $CH_3-\overset{\bullet}{C}H-CH_2Br$.

Step 3 – abstract hydrogen: This radical takes an H from HBr, placing H on the middle carbon and Br on the terminal carbon.

Step 4 – name the product: Bromine ends up on the terminal (1) carbon, giving 1-bromopropane (anti-Markovnikov).

Final Answer: major product $=$ 1-bromopropane $\Rightarrow \boxed{A}$

Answer: (A) Go Back to Q36

Q37.

Solution

Concept – reducing sugars and the free carbonyl: A sugar is "reducing" if it has a free carbonyl that can be oxidized (reducing Ag^{+} in Tollens' test).

Step 1 – read the open-chain structure: The Fischer projection of glucose shows a $-CHO$ group at C1, i.e. an aldehyde.

Step 2 – link the group to the test: The free aldehyde is oxidized to a carboxylate ($-COO^{-}$) while Ag^{+} is reduced to metallic silver (the mirror).

Step 3 – classify glucose: An aldose with a free $-CHO$ is a reducing sugar; hence the responsible group is the aldehyde.

Final Answer: responsible group = free aldehyde $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q37

Q38.

Solution

Concept – selective oxidation of a primary alcohol to an aldehyde: Stopping at the aldehyde needs a mild, anhydrous oxidant that will not carry on to the acid.

Step 1 – reject the strong aqueous oxidants: Hot acidic $KMnO_4$, acidic $K_2Cr_2O_7$ and Jones reagent all over-oxidize a primary alcohol straight through to the carboxylic acid.

Step 2 – pick the mild reagent: Pyridinium chlorochromate (PCC) in dry dichloromethane oxidizes RCH_2OH only as far as $RCHO$.

Step 3 – give the reason: The anhydrous conditions of PCC prevent formation of the hydrate that the further oxidation to acid requires.

Final Answer: selective reagent = PCC $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q38

Q39.

Solution

Concept – the Rosenmund reduction: An acyl chloride is reduced to an aldehyde by H_2 over a deliberately poisoned palladium catalyst.

Step 1 – write the transformation: $RCOCl \xrightarrow{H_2,\ Pd/BaSO_4} RCHO$

Step 2 – explain the poisoning: The $BaSO_4$ support (often with quinoline/sulfur) tempers the catalyst so the reaction stops at the aldehyde and does not go on to

the alcohol.

Step 3 – distinguish from other reductions: Clemmensen and Wolff–Kishner reduce $C{=}O$ fully to CH_2; Birch reduces aromatic rings; none of these makes an aldehyde from an acyl chloride.

Final Answer: the reaction is the Rosenmund reduction $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q39

Q40.

Solution

Concept – electrophile in Friedel–Crafts alkylation: $AlCl_3$ is a Lewis acid that abstracts halide from the alkyl halide to generate a carbocation electrophile.

Step 1 – form the electrophile: $CH_3Cl + AlCl_3 \rightarrow CH_3^+ + AlCl_4^-$

Step 2 – identify the attacking species: The methyl carbocation CH_3^+ is the true electrophile that attacks the benzene ring.

Step 3 – complete the picture (conceptually): The ring π-electrons attack CH_3^+ to give an arenium ion, which loses H^+ to restore aromaticity, yielding toluene.

Why the others are wrong: $AlCl_4^-$ is the counter-ion, not the electrophile; a chloronium ion or a methyl radical does not form under these ionic Lewis-acid conditions.

Final Answer: electrophile $= CH_3^+ \Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q40

Q41.

Solution

Concept – osazone formation from sugars: Excess phenylhydrazine reacts with both $C1$ and $C2$ of an aldose to give a bis-phenylhydrazone called an osazone.

Step 1 – react at $C1$: The first molecule of phenylhydrazine condenses with the $C1$ aldehyde to form a phenylhydrazone.

Step 2 – oxidize and react at $C2$: A second phenylhydrazine oxidizes the $C2$ hydroxyl to a carbonyl, and a third forms a second phenylhydrazone there.

Step 3 – name the product: The resulting crystalline bis-phenylhydrazone at $C1$ and $C2$ is the osazone (from glucose, glucosazone).

Final Answer: product $=$ osazone (glucosazone) $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q41

Q42.

Solution

Concept – the Wolff–Kishner reduction: Hydrazine plus a strong base, under heat, reduces a carbonyl $C{=}O$ all the way to a methylene CH_2 under basic conditions.

Step 1 – form the hydrazone: The ketone reacts with NH_2NH_2 to give a hydrazone $R_2C{=}N{-}NH_2$.

Step 2 – decompose it with base: Strong base (KOH) and heat expel N_2, leaving R_2CH_2.

Step 3 – contrast with Clemmensen: Clemmensen achieves the same $C{=}O \rightarrow CH_2$ result but under *acidic* $Zn(Hg)/HCl$ conditions; here the conditions are basic, so it is Wolff–Kishner.

Final Answer: the reaction is the Wolff–Kishner reduction $\Rightarrow$ B

Answer: (B) Go Back to Q42

Q43.

Solution

Concept – the glycosidic bond: Monosaccharide units are joined into di- and polysaccharides through glycosidic bonds formed between anomeric carbons and hydroxyl groups, with loss of water.

Step 1 – identify the units in sucrose: Sucrose is made of one glucose and one fructose unit.

Step 2 – identify the connecting atoms: They are joined through the anomeric $C1$ of glucose and the anomeric $C2$ of fructose.

Step 3 – classify the linkage: A bond between a sugar's anomeric carbon and another unit is, by definition, a glycosidic bond (an α, β-$1,2$ glycosidic linkage here).

Final Answer: the linkage is a glycosidic bond $\Rightarrow$ C

Answer: (C) Go Back to Q43

Q44.

Solution

Concept – classifying the Diels–Alder reaction: A cycloaddition is labelled $[m+n]$ by the number of π electrons each partner contributes.

Step 1 – count the π electrons of each partner: The diene supplies 4π electrons and the dienophile supplies 2π electrons.

Step 2 – assemble the label: Combining a 4π and a 2π component gives a $[4+2]$ cycloaddition.

Step 3 – confirm it is allowed: A thermal $[4+2]$ ($4n+2$ total electrons) is symmetry-allowed suprafacial–suprafacial, forming two new σ bonds and the cyclohexene ring in one concerted step.

Final Answer: Diels–Alder is a $[4+2]$ cycloaddition $\Rightarrow$ $\boxed{\text{D}}$

Answer: (D) Go Back to Q44

Q45.

Solution

Concept – Woodward–Hoffmann rules for electrocyclic reactions: For a $4n+2$ π-electron system, the thermal mode is disrotatory and the photochemical mode is the opposite, conrotatory.

Step 1 – count the π electrons: A conjugated triene has 6 π electrons, so $4n+2$ with $n=1$.

Step 2 – recall the thermal rule: Thermally, a $4n+2$ system closes disrotatory.

Step 3 – invert for photochemistry: Photochemical excitation reverses the selection rule, so the allowed mode becomes conrotatory.

Step 4 – conclude: The photochemical 6π electrocyclic ring closure is conrotatory.

Final Answer: photochemical 6π closure is conrotatory $\Rightarrow$ $\boxed{\text{C}}$

Answer: (C) Go Back to Q45

Q46.

Solution

Concept – the anomeric carbon: Anomers are cyclic sugars that differ in configuration only at the carbon formed from the open-chain carbonyl (the anomeric carbon).

Step 1 – locate the carbonyl of open-chain glucose: Glucose is an aldose with

its carbonyl at C1.

Step 2 – form the ring: On ring closure, C1 becomes a new stereocentre bearing the hemiacetal $-\mathrm{OH}$.

Step 3 – identify where α and β differ: α- and β-D-glucopyranose differ in the orientation of the $-\mathrm{OH}$ at this new stereocentre, i.e. at C1.

Step 4 – name it: C1 is the anomeric carbon.

Final Answer: anomeric carbon $=$ C1 $\Rightarrow \boxed{\mathrm{D}}$

Answer: (D) Go Back to Q46

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	A	3	D	4	C	5	C
6	B	7	D	8	A	9	C	10	A
11	D	12	A	13	A	14	B	15	C
16	B	17	B	18	D	19	A	20	C
21	C	22	D	23	A	24	C	25	C
26	A	27	B	28	B	29	D	30	D
31	B	32	B	33	A	34	A	35	B
36	A	37	C	38	D	39	B	40	B
41	D	42	B	43	C	44	D	45	C
46	D								